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PLUS Traffic Highway: An Analysis Based on Time Series Similarity Approach

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Abstract: Highway is the backbone of a country's transportation system. The highway development is very important to a country to overcome the demand for efficient road transportation. Better interconnected road network is crucial to increase the economic activities and social development in a country. The Malaysian government is highly committed towards the development of road network. Projek Lebuhraya Usahasama Berhad (PLUS) is one of the highway operators in Malaysia. It is also the largest highway concessionary or Build-Operate-Transfer (BOT) operator company in Malaysia. As the largest highway concessionary in Malaysia, the network analysis of PLUS highway development was studied in this study. The data used were based on the number of vehicles that enter and exit each PLUS toll Plazas from Juru (JRU) toll plaza to Skudai (SKD) toll plaza. The relationships between the toll plazas were studied by using minimal spanning trees and the overall centrality measures were used to determine the most influential toll plazas among the states. Based on the results, some recommendations are forwarded to the PLUS highway to improve the services and to increase the traffic efficiency.

Key words: Centrality measures, minimal spanning tree, network topology, topological properties of toll plaza, recommendations

INTRODUCTION

Malaysia now is heading to globalization, the economic growth is rapidly increasing and at the same time the patterns of transportation also follow the transformation of economic expansion. The growth of Malaysian highway network is the results from and cause of these positive progresses of industrialization. The demand of traveling increases as the need of mobility in manufacturing sectors for demands and supplies continue. Other factors that influence the demand of traveling are the rapid urban development and also the population growth.

The government of Malaysia is highly committed in building the development of road network. According to the Department of Statistics, Malaysia, the road mileage in Malaysia is increasing from 135,226 km in year 2009-180,882 km in year 2012. The number of registered motor vehicles also increases from 20,188,565 in year 2010-22,702,221 in year 2012. The highest number of registered motor vehicles is motorcycles followed by motorcar, taxi and hired car, bus, goods vehicles and other vehicles. The rising of road mileage and registered vehicles shows that Malaysia really need good road networks as these statistics will increase year by year.

Many study about road network in Malaysia are focused on transportation planning (Shariff, 2012), public transportation (Ismail *et al*., 2012; Zakaria *et al*., 2010), road transport demand (Ubaidilla, 2013), urban transport (Almselati *et al*., 2011) and many more. Shariff (2012) suggested that there should be public debates over urban growth patterns and transportation sustainability in the rapidly developing cities of Malaysia. In order to reduce the vehicular emission which can leads to health and environmental damages, the enforcement of urban planning, environmental regulation and transport policies is crucial. Ubaidilla (2013) suggested that the policy makers have to provide greater and more efficient public transportation system to all states in Malaysia since her findings showed the demand for road transport is increasing.

In this study, the social network analysis is used to analyze the current portrait of PLUS highway traffic. The PLUS highway traffic development had been our interest because this highway has been one of the busiest highways in Peninsular Malaysia. A lot of vehicles utilize

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this highway every day. The number of vehicles that enters and exits for each PLUS toll plazas from JRU toll plaza to SKD toll plaza was collected as the main data. The relationships between the toll plazas were also investigated. The centrality measures such as closeness, betweeness, degree and eigenvector centralities are used to determine the most influential toll plazas. Furthermore, an overall centrality measure, defined by the first principal component is introduced.

MATERIALS AND METHODS

Data collection: The data for this research were collected from the Toll Department, PLUS Malaysia Sdn. Bhd. Those data were based on the number of vehicles that entered and exited at each PLUS toll plazas from JRU toll plaza to SKD toll plaza. The data collected were from July, 2009 until April 2013. There were 65 toll plazas involved and they were located in Penang (4 toll plazas), Kedah (1 toll plaza), Perak (14 toll plazas), Selangor (23 toll plazas), Wilayah Persekutuan (3 toll plazas), Negeri Sembilan (5 toll plazas), Malacca (3 toll plazas) and Johor (11 toll plazas). The number of vehicles studied is categorized as import and export. Export from A-B means the total number of vehicles that exit A toll plaza to B toll plaza. On the other hand, import is defined as the total number of vehicles that enter A from B toll plaza.

Data preparation and analysis: The steps involved in the social network analysis approach are discussed briefly in this section to understand the relationships between the toll plazas and to identify the most influential toll plazas in terms of centrality measures. The dissimilarity matrix or more specifically distance matrix is used to determine the MST. The data matrix for number of vehicles from July 2009-April 2013 is transformed into distance matrix, D, using this Eq. 1:

$$D = \text{Maximum value} - a_{ij} \quad (1)$$

For all i, j = 1, 2, ..., n where a_{ij} refers to the element (i, j) in the distance matrix and n here refers to the number of toll plazas studied which are 65 toll plazas.

Based on distance matrix D, the network among toll plazas is analyzed using the Minimal Spanning Tree (MST). MST is constructed to visualize the important information contained in the network in D in terms of topological properties. MST is a concept in graph theory to filter the information contained in a weighted connected graph of n objects (nodes). It is a tree with (n-1) edges (links) that minimizes the sum of the weights (distances in our case). MST is built by linking every element in a set of n together in a graph characterized by a minimal distance between the nodes. The most widely used method to construct an MST is known as Kruskal's and Prim's algorithm (Mantegna and Stanley, 2000).

After the network topology of the entire toll plazas had been constructed, the Pajek Software was used to visualize the network. Then, an analysis is conducted to understand the importance of each node relative to the others in terms of centrality measures (Borgatti, 2005). There are three different concepts of centrality as discussed by Hanneman and Riddle. The three concepts are degree centrality, closeness centrality and betweenness centrality while Borgatti (1995) defines four measures of centrality called eigenvector centrality. Below is the measurement of those centralities (Borgatti, 2005):

- Degree centrality is defined as the number of ties that a given node has. The degree of node i given by $d_i = \sum_{j=1}^{n} \delta_{ij}$ where δ_{ij} is the Kronecker's delta. It is 1 if the i-th and j-th nodes are linked and 0 otherwise
- Closeness centrality is defined as the total graph theoretic distance of a given node from all other nodes $c_i = \sum_j d_{ij}$ where d_{ij} is the number of links in the shortest path from i-j
- Betweenness centrality is the number of shortest paths that pass through a given node $b_i = \sum_{i,j} g_{ijk}/g_{ij}$ where g_{ij} is the shortest path from node i to node j and g_{ikj} is the shortest path from i-j that passes through k
- Eigenvector centrality or known as a variant of simple degree. Eigenvector centrality of node i is $e_i = \lambda^{-1} \sum_j a_{ij} e_j$ where λ is the eigenvalue of the adjacent matrix D = (a_{ij}) associated to eigenvector e_i

Some applications of those centrality measures can be found in (Yusoff *et al*., 2012; Djauhari *et al*., 2012; Lee and Djauhari, 2012; Naylor *et al*., 2007). Since each centrality measure was defined for special purpose, it is not relevant to select the best measure among them. Therefore, in this case, we need an overall centrality measure. The application of this measure can be found in (Lee and Djauhari, 2012; Asrah *et al*., 2014). This measure is defined by using the principal component analysis on the data matrix M of size (n×4) where the first until the fourth column represents the scores of n nodes according to degree, betweenness, closeness and eigenvector centralities. The score of node i in terms of the overall centrality measure is given by:

$$O_i = e_1 C_D(i) + e_2 C_B(i) + e_3 C_C(i) + e_4 C_E(i) \quad (2)$$

where, e = (e_1, e_2, e_3, e_4)^t is the eigenvector of covariance matrix S from M with the largest eigenvalue.

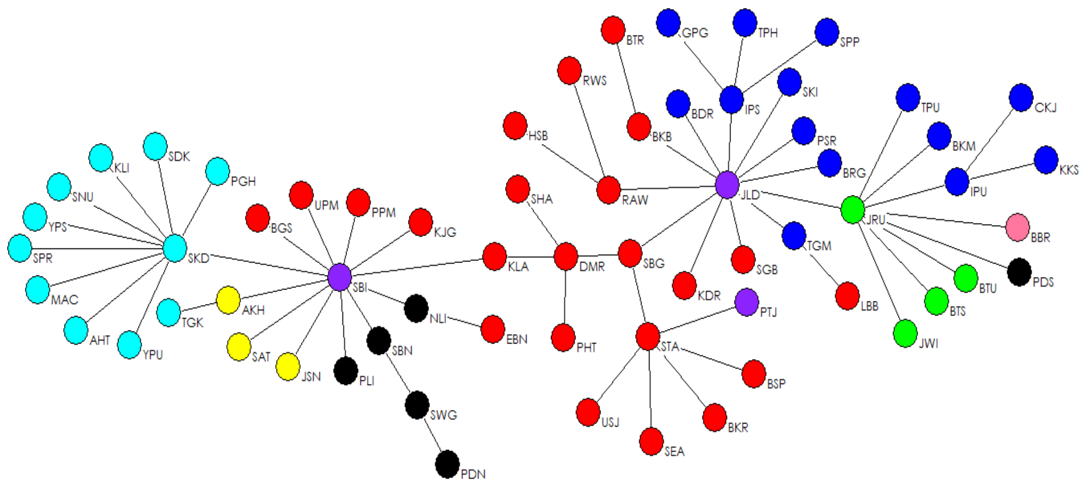

Fig. 1: Similarities network among PLUS toll plazas for export category

RESULTS AND DISCUSSION

Network topology: Figure 1 and 2 present the similarities network among PLUS toll plazas for export and import categories, respectively. This is an MST issued from Kruskal's algorithm which will help us to filter the important information contained in the whole network such as the relationship between toll plazas with high similarity. The different colours in this network topology represent the different states of toll plazas. Penang is represented in green colour, Kedah in magenta, Perak in blue, Selangor in red, Negeri Sembilan in black, Malacca in yellow, Johor in cyan and Wilayah Persekutuan in purple.

From Fig. 1, there are four toll plazas dominate the network for export category. The four toll plazas are show in Table 1.

MST here represents the correlation or the similarity behavior among toll plazas. These four toll plazas are connected to the other toll plazas with high number of connections. Toll plazas with highest connection are JLD and SBI toll plazas. The second highest connection is SKD toll plaza and followed by JRU toll plaza. From these connections, it has been noted that the JLD toll plaza is more likely or similar to vehicles entering from Perak and Selangor. Meanwhile, the SBI toll plaza is more likely or similar to vehicles entering from Selangor, Malacca and Negeri Sembilan. JLD toll plaza is more likely or similar to vehicles entering from the northern locations while the SBI toll plaza is more likely or similar to vehicles entering from the central and southern locations. The toll plaza in the northern, JRU toll plaza is more likely or similar to vehicles entering from Kedah, Perak, Penang, Negeri Sembilan and Wilayah Persekutuan. Surprisingly, the southern location of the toll plaza, SKD is more likely or similar to vehicles entering from Wilayah Persekutuan and Johor only. It has been observed that the JLD toll plaza is the most crucial plaza toll on this highway for export category compared to the rest.

Table 1: The top four toll plazas with highest connections for export category

Rank	Toll plaza	State
1	JLD(Jalan Duta)	Wilayah
	SBI(Sungai Besi)	Persekutuan
2	SKD(Skudai)	Johore
3	JRU(Juru)	Penang

Table 2: The top four toll plazas with highest connections for import category

Rank	Toll plaza	State
1	JLD(Jalan Duta)	Wilayah Persekutuan
2	SBI(Sungai Besi)	Wilayah Persekutuan
3	SKD(Skudai)	Johore
	JRU(Juru)	Penang

Figure 2 presents the similarities network among PLUS toll plazas for import category. In total, there are four toll plazas that dominated the network. Those toll plazas are show in Table 2.

These four toll plazas are connected to the others toll plaza with a high number of connections. Toll plaza with highest connection is JLD toll plaza. The second highest connection is SBI toll plaza and followed by JRU and SKD toll plazas. Toll plaza JLD has more likely or similar to vehicles that exit to Perak and Selangor. Meanwhile, toll plaza SBI has more likely or similar to vehicles that exit to Selangor, Malacca and Negeri Sembilan. It shows that toll plaza JLD has more likely to vehicles that exit to the central and northern locations while toll plaza SBI has more likely to vehicles that exit to the central and southern locations. The toll plaza in the northern location, JRU has

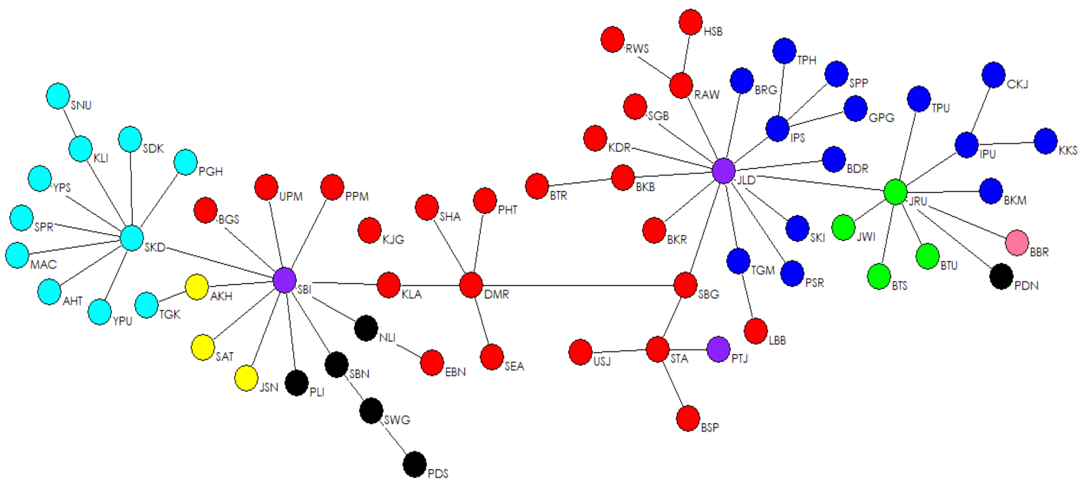

Fig. 2: Similarities network among PLUS toll plazas for import category

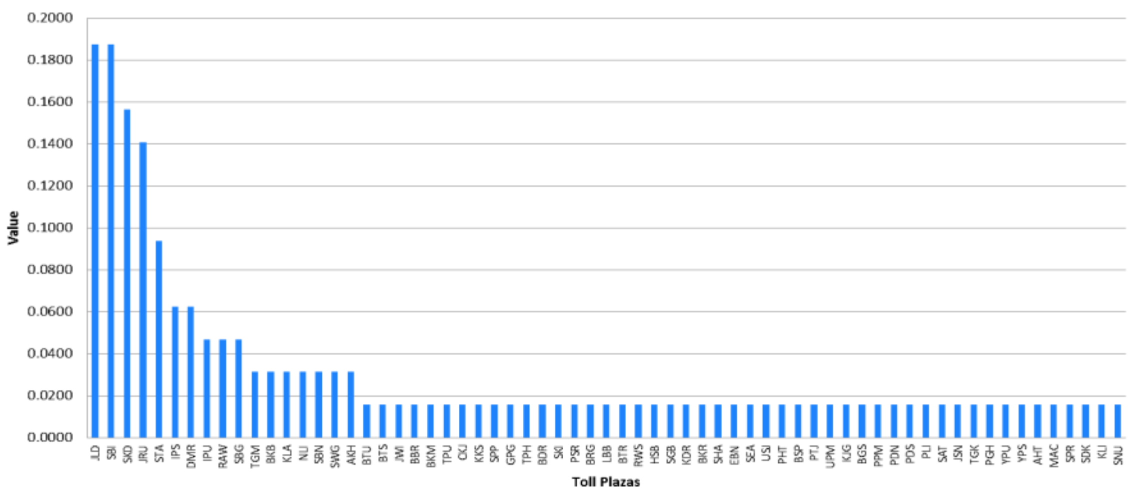

Fig. 3: Degree centrality measurement among PLUS toll plazas for export category

more likely or similar to vehicles that exit to Kedah, Perak, Penang, Negeri Sembilan and Wilayah Persekutuan. SKD, the toll plaza at the southern location has more likely or similar to vehicles that exit to Wilayah Persekutuan and Johore only. Hence, SBI toll plaza is the most crucial plaza toll on this highway compared to the others.

Centrality measure: Centrality measures are used to analyze the most important node in the network structure. It also measured the involvement of the node in the network (Opsahl *et al*., 2010). It explains how nodes play an important role in social network structure.

Results for export category: The results of export category in Table 3 show that JLD and SBI toll plazas scored the highest for degree centrality (0.1875), the second highest is SKD toll plaza (0.1563) and the third highest is JRU toll plaza (0.1406). Toll plazas with higher scores in degree centrality could have crowded traffic compared to the toll plazas with lower scores and the location of the toll plaza is more central compare to the others. This is because these toll plazas have more connections and links to many other toll plazas. In export category, JLD and SBI toll plazas are the most crucial among the PLUS toll plazas. Both toll plazas influence the other toll plazas and are the most important toll plazas for export category. Figure 3 shows the bar chart of the

Table 3: Centrality measures scores for PLUS toll plazas for export category

Degree	Betweenness	Closeness	Eigenvector	Overall
JLD (0.1875)	JLD (0.6538)	SBG (0.3092)	JLD (0.5274)	JLD (0.0081)
SBI (0.1875)	SBG (0.5898)	JLD (0.2991)	JRU (0.3276)	SBI (0.0078)
SKD (0.1563)	SBI (0.5893)	DMR (0.2991)	SBI (0.3129)	SKD (0.0058)
JRU (0.1406)	DMR (0.5263)	KLA (0.2891)	SKD (0.2254)	JRU (0.0054)
STA (0.0938)	KLA (0.4836)	SBI (0.2645)	SBG (0.1833)	DMR (0.0038)

degreecentrality scores for export category clearly. Betweenness centrality explains how a toll plaza controls the others toll plazas which have no direct connectivity between them. This measure counts the frequency a toll plaza intervened to connect the others and investigates the whole network to find the connecting path. It also tell us how a toll plaza is important to reach the destination from the starting point. The higher value of betweenness means that the toll plaza plays an important role to connect the other toll plazas. Toll plazas with lower scores indicate as being less important in connecting the other toll plazas. These nodes are usually a leaf node in a network. JLD toll plaza has the highest score for the betweenness centrality (0.6538), the second highest is SBG (Subang) toll plaza (0.5898) and the third is SBI toll plaza (0.5893). These three toll plazas are the most important toll plazas and play important roles to reach the origin from the destination. They also have high potential to control the traffic flow in the network.

Next, the closeness centrality indicates how a toll plaza is close to the other toll plazas (Newman, 2008). The shortest distance paths between the toll plazas are computed and this indicates the distance between the toll plazas. Park and Yilmaz explained closeness in the highway indicates how far from one toll plaza to the other toll plaza. The larger the value of the scores means that the toll plaza does not have the shortcut path to arrive to the other toll plazas. For export category, SBG toll plaza scored the highest (0.3092) followed by JLD and DMR toll plazas (0.2991). Next is KLA (KLIA) toll plaza with (0.2819). These toll plazas have excellent positions as the traffic flow in the network could reach the other toll plazas quickly compared to other plazas. These toll plazas do not need a shortcut path to reach the other toll plazas. The eigenvector centrality measured the strength and the importance of a toll plaza with its connections to others important and influence toll plazas. The importance of a toll plaza depends on the importance of its neighbors (Perra and Fortunato, 2008). The toll plazas with high scores represents that they are connected to the other important toll plazas. JLD toll plaza has the highest score (0.5274) in this centrality followed by JRU toll plaza (0.3276) and SBI toll plaza (0.3129). JLD toll plaza influenced the other toll plazas with higher scores. By looking at the four centrality measures, the top five toll plazas with the highest scores for three or four measures were JLD, SBI, JRU and SBG toll plazas. These toll plazas have been the important toll plazas in the PLUS highway and appeared as part of the higher scored toll plazas for all the centrality measures. The score of each centrality measure has different roles or functions. Thus, if it is needed, the overall centrality measure can be taken into account to find the most important toll plaza regardless the four measures mentioned above. The results are as follows. The highest scores for the overall centrality was JLD toll plaza (0.0081), followed by SBI toll plaza (0.0078) and SKD toll plaza (0.0058).

Results for export category: While results on import category in Table 4 show that the JLD toll plaza scored the highest for degree centrality (0.2031), followed by SBI toll plaza for the second highest score (0.1875) and the third are JRU and SKD toll plazas (0.1406). Toll plazas with higher scores in degree centrality could have crowded traffic compared to the toll plazas with lower scores and the location of the toll plaza is more central compare to the others. This is because these toll plazas have more connections and links to many other toll plazas. In import category, JLD toll plaza is the most crucial among the PLUS toll plazas. This toll plaza influences the other toll plazas and be the most important toll plazas for import category. Figure 4 shows the bar chart of the degree

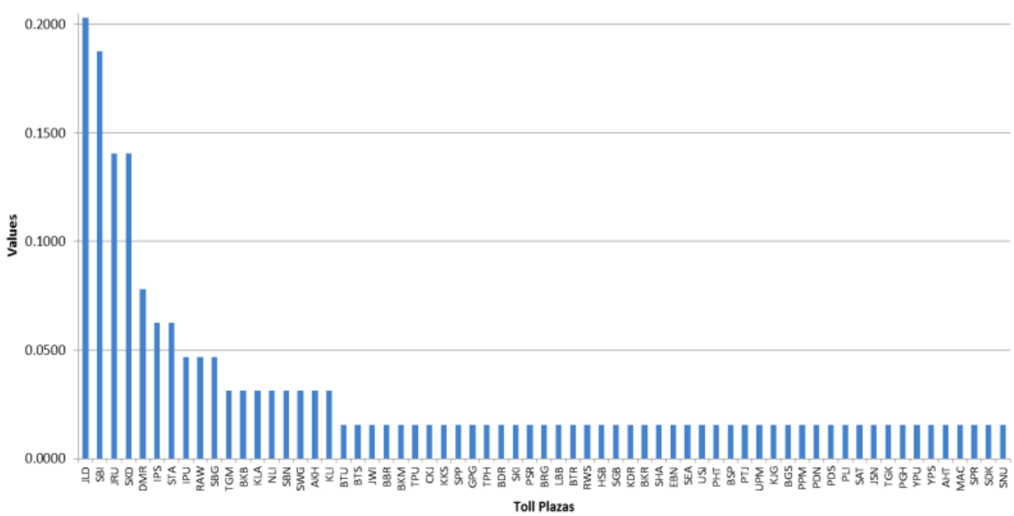

Fig. 4: Degree centrality measurement among PLUS toll plazas for import category

Table 4: Centrality measures scores for PLUS toll plazas for export category

Degree	Betweenness	Closeness	Eigenvector	Overall
JLD (0.2031)	JLD (0.6721)	SBG (0.3077)	JLD (0.6315)	JLD (0.0110)
SBI (0.1875)	SBI (0.5883)	JLD (0.3005)	JRU (0.3587)	SBI (0.0098)
JRU (0.1406)	SBG (0.5655)	DMR (0.3005)	IPS (0.2042)	JRU (0.0064)
SKD (0.1406)	DMR (0.5437)	KLA (0.2832)	SBG (0.1992)	DMR (0.0062)
DMR (0.0781)	KLA (0.4836)	SBI (0.2656)	RWG (0.1884)	SKD (0.0061)

centrality scores for import category clearly. JLD toll plaza has the highest score for betweenness centrality (0.6721), the second highest is SBI toll plaza (0.5883) and the third is SBG toll plaza (0.5655). These three toll plazas are the most important ones and play important roles to reach the destination from the origin. These toll plazas have high potential to control the traffic flow in the network.

Next, in terms of closeness centrality, SBG toll plaza scored the highest (0.3077), followed by JLD and DMR toll plazas (0.3005) and KLA toll plaza (0.2832). These toll plazas have excellent positions as the traffic flow in the network could reach these toll plazas quickly compared to the others. These toll plazas do not need a shortcut path to reach the other toll plazas.

On the other hand, JLD toll plaza has the highest score (0.6315) in the eigenvector centrality, followed by JRU toll plaza (0.3587) and IPS (Ipoh Selatan) toll plaza (0.2042). JLD toll plaza influenced the other toll plazas with higher scores.

By looking at the four centrality measures, the top five toll plazas with the highest scores for three or four measures are SBI, JLD, SBG and JRU. These are the important toll plazas in the PLUS highway and appeared as part of the high scored toll plazas for all four centrality measures. However, according to the overall centrality measure, the highest scores are for JLD toll plaza (0.0110), followed by SBI toll plaza (0.0098) and JRU toll plaza (0.0064).

CONCLUSION

JLD toll plaza is found to be the most important toll plaza on the PLUS highway for export category. This toll plaza scored the highest results for degree centrality, betweenness centrality, eigenvector centrality and overall centrality measures. Meanwhile, SBI toll plaza scored the second highest results for degree and overall centralities and the third highest result for betweenness and eigenvector centralities. SKD toll plaza scored the third highest result for degree and overall centralities the fourth highest in eigenvector centrality. JLD and SBI toll plazas have many connections with other toll plazas. They have very high potential to control the traffic flow in the PLUS highway and are the most important toll plazas in the PLUS highway. They also receive the highest number of vehicles that enter from both the southern and the northern destinations.

Similarly, JLD toll plaza is found to be the most important toll plaza on the PLUS highway for import category. This toll plaza scored the highest results for degree, betweenness, eigenvector and overall centralities and the second highest score for closeness centrality measure. Meanwhile, SBI toll plaza scored the second highest results for degree, betweenness and overall centralities. JRU toll plaza scored the second highest results for eigenvector centrality and third highest results for degree and overall centralities.

JLD and SBI toll plazas have many connections with other toll plazas. They have very high potential to control the traffic flow in the PLUS highway and are the most important toll plazas in the PLUS highway. They also receive the highest number of vehicles that enter from the southern and the northern destinations.

RECOMMENDATIONS

Based on the results using data from July 2009-August 2013, it recommended that PLUS have to improve their services and the development of highways for JLD, SBI, JRU and SKD toll plazas. This is because JLD and SBI toll plaza are the most important toll plaza for both categories, import and export. These toll plazas have many connections with other toll plazas in all state. While JRU and SKD toll plazas are the most important toll plazas in northern and southern states.

In the next 5 years, the number of vehicles will increase. In order to avoid the daily traffic or during the festival seasons, PLUS have to increase the number of lanes and upgrading the roads. Upgrading the roads here can be to wider the lanes, improve the quality of the roads, increase the number of street lights, increase the number of street dividers and many more. The safety factors should be taken into account too. PLUS have to increase the facilities along the highway such as emergency telephone system, speed detector, variable message signboard for information on traffic congestion, accidents, landslide, flood and many more.

Meanwhile, PLUS also have to put consideration on JRU and SKD toll plazas because these toll plazas also play an important role in the network. SKD toll plaza is the important toll plaza in this network for export category especially for vehicles in southern area. While JRU toll plaza is the important toll plaza for import category especially for vehicles in northern area. Both toll plaza will be growing and will be one of the most important toll plaza in the future. It also recommended that PLUS have to find an alternative way to prevent the traffic congestion for example to open new toll plaza so that it can help to cover the number of increasing vehicles using this highways.

In the next study, an updated database which cover long time support would be used to forecast the future situation of PLUS highway traffic flow. For this purpose, data collection process is still ongoing.

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REFERENCES

Almselati, A.S.I., R.A.O.K. Rahmat and O. Jaafar, 2011. An overview of urban transport in Malaysia. The Social Sci., 6: 24-33.

Asrah, N.M., M.A. Djauhari and E.S. Suleiman, 2014. Work attitude among malaysian academicians in the public universities: A social network analysis. Mod. Appl. Sci., 8: 9-18.

Borgatti, S.P., 1995. Centrality and AIDS. Connections, 18: 112-115.

Borgatti, S.P., 2005. Centrality and network flow. Social Netw., 27: 55-71.

Djauhari, M.A., S. Sharif and H. Djauhari, 2012. Network analysis on safety culture and worker‘s behaviour: A forest of all minimum spanning trees. Int. J. Basic Appl. Sci., 12: 29-37.

Ismail, R., M.H. Hafezi, R.M. Nor and K. Ambak, 2012. Passengers preference and satisfaction of public transport in Malaysia. Aust. J. Basic Applied Sci., 6: 410-416.

Lee, G.S. and M.A. Djauhari, 2012. An overall centrality measure: The case of us stock market. Int. J. Electr. Comput. Sci., 12: 99-103.

Mantegna, R.N. and H.E. Stanley, 2000. An introduction to econophysics: Correlation and Complexity in Finance. Cambridge University, Cambridge, UK., ISBN: 9780521620086, Pages: 148.

Naylor, M.J., L.C. Rose and B.J. Moyle, 2007. Topology of foreign exchange markets using hierarchical structure methods. Physi. A. Statist. Mechan. Applic., 382: 199-208.

Newman, M.E., 2008. The mathematics of networks. N. Palgrave Encycl. Econ., 2: 1-12.

Opsahl, T., F. Agneessens and J. Skvoretz, 2010. Node centrality in weighted networks: Generalizing degree and shortest paths. Social Networks, 32: 245-251.

Perra, N. and S. Fortunato, 2008. Spectral centrality measures in complex networks. Phys. Rev. E, Vol. 78. 10.1103/PhysRevE.78.036107.

Shariff, N.M., 2012. Private vehicle ownership and transportation planning in Malaysia. Int. Conf. Traffic Transp. Eng., 1: 64-68.

Ubaidilla, N.Z., 2013. An econometric analysis of road transport demand in Malaysia. Int. J. Bus. Tourism Appl. Sci., 1: 65-73.

Yusoff, N.S., M.A. Djauhari, S. Sharif and E.S. Suleiman, 2012. Organizational commitment in Malaysian public university: An evidence via social network analysis. Int. J. Basic Appl. Sci., 12: 17-21.

Zakaria, Z., Z.H. Hussin, M.F.A. Batau and Z. Zakaria, 2010. Service quality of Malaysian public transports: A case study in Malaysia/la qualite de service de transports publics Malaisiens. Cross Cult. Commun., 6: 84-92.